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March 31, 1999

To: Mr. John Yearsley, Environmental Protection Agency
Region 10
1200 Sixth Avenue
Seattle, Washington

From: Dave Wegner
Ecosystem Management International, Inc.
Principal Scientist

Subject: Review Comments of Technical Report
**Columbia River Temperature Assessment: Simulation Methods**

I have received and reviewed the technical report entitled ***Columbia River Temperature Assessment: Simulation Methods***. I have reviewed the documentation that you provided and have evaluated your approach, assumptions and results based on my experience and historic application of thermal models in the Colorado River basin.

My review follows the following outline and represents the major areas that your report addresses. My review approach has focused on three primary representations.

- Conceptual Representation - has the logic for development of the model been adequately laid out and are the steps for application clearly defined?
- Functional Representation - has the formulation of the model, specifically the physical constraints, process, variables, and boundary conditions been adequately defined?
- Computational Representation - does the model adequately translate the logic into correct mathematical forms and procedures necessary for solution of the problem over the desired temporal and spatial spectrum?

My primary expertise lies in the evaluation of the Conceptual and Functional representation arenas. These two areas must be credibly and accurately defined if an accurate assessment is to be completed on the thermal conditions in the Snake and Columbia Rivers.

## MODEL PEER REVIEW FOCUS QUESTIONS

### Part I. Conceptual Model

**(1) Have the objectives of the temperature model been clearly identified?**

In general yes. Additional clarification is needed in regards to who will be using this model, what level of detail is required in their use, and if this model will be used to set TMDL limits.

**(2) Has the level of certainty required by the model objectives been identified and can the proposed concept achieve this level of certainty?**

In regards to the objective of developing a screening model, this assessment has achieved its goal. Applications above the screening level however require additional clarification, statistical analysis and a more rigorous assessment of the error bias.

**(3) Have the appropriate system boundaries, time scales and length scales been identified?**

For a screening model assessment the appropriate boundaries and scales have been identified in general except for inclusion of addressing the boundaries related to reservoir dynamics behind the study dams. This area needs to be expanded upon (see comments below).

**(4) Have the important source terms and background conditions been identified and are there adequate data to characterize them sufficiently for the model application?**

In general yes. The assessment does a good job of identifying the necessary model parameters and the data necessary for application. The boundary conditions for the reservoir and pre-project thermal and flow conditions however should be further articulated.

**(5) Are the available data adequate for achieving the levels of certainty required by the model objectives?**

For a screening level model the answer is yes.

### Part II. Model Development

**(1) Is the model being developed based on current knowledge and do the mathematical descriptions accurately reflect the processes identified in the conceptual model?**

Yes, the model is based on the present state of the art.

**(2) What structural properties in the model cold affect reliability of model predictions?**

- Reservoir limnology is not dealt with directly and should be.
- The physical geometry needs to be beefed up for any level of analysis beyond the screening level.
- System, both physical and limnological, variability is not addressed adequately for anything beyond a screening level approach.
- The statistical significance of the results has not been addressed and should be before the report is finalized.

- Temporal and spatial variability should be discussed as related to implications to model results

**(3) Is the parameter estimation process reasonable in terms of available data and knowledge?**

For a screening level assessment the answer is Yes.

**(4) Is there a well designed plan for determining if and when the model is acceptable for use as a decision-support tool?**

A rigorous statistical evaluation of the results is necessary before providing this tool to decision-makers. Additionally an assessment on how this model should be used must be developed before it is put on the street. There is not a plan presented in the report and there should be.

**(5) Are all components of the conceptual model realized in the model development?**

As developed for a screening process the answer is Yes. However there are several critical areas that should be discussed and evaluated prior to further application:

- Inclusion of reservoir and hydrologic dynamics
- Inclusion of a statistical analysis of results
- Clarification of model application. The parameters, especially the innovation process needs to be explained further
- The model approach has been well done for the level of answer desired. My fear is that the public will rush to conclusions without fully understanding the constraints necessary in interpreting the results or that this was a screening level assessment.

**Part III.**

**(1) Do the model results adequately address all the objectives?**

The results address the objective of developing a screening model. The results do not address the cause for the increase temperatures (dams, watershed development, or hydrologic modification). It is clear that something has raised the temperature and it is probably in a priority based on: (1) dams; (2) changes in regimes; (3) watershed impacts. Care should be taken with a screening level study of jumping too far out on the limb.

**(2) Do the results properly characterize the uncertainty and variability associated with data collection, source characteristics a model error?**

At a screening level model the answer is yes. Additional work should be done however to address the impacts related to the reservoirs, retention time, and statistical significance of the differences in the results.

**(3) Are the conclusions reasonable in terms of the model and data uncertainty and variability?**

Yes with the caveat that a statistical evaluation of the significance of the difference as related to the model error should be made before the conclusions are made public.

**(4) Is the work documented well enough such that others could reproduce the results?**

Yes IF the comments made below are addressed.

Overall I feel that the approach, methodology and application was very well done for the level of analysis described. My specific comments included below represent my review of the document and my attempt to make the document more readable to the interested public and decision-makers. My hope is that the document will reach the necessary managers and result in support for expansion of the study to include a more rigorous evaluation of the model, the variability of the system and the application to additional alternatives.

## SPECIFIC COMMENTS ON THE REPORT

### I. Introduction and Background

The objectives of the report is stated *to assess the relative importance of different sources of watershed impact in respect to changes in the temperature regime of the main stem Columbia River in Washington and Oregon and in the Snake River in Washington.* Three general sources of river impact are identified:

1. Construction of impoundments for hydroelectric facilities and navigational locks.
2. Hydrologic modification to the natural river system as related to irrigation and navigational development
3. Modification of the watershed from agricultural and silviculture practices which reduce riparian vegetation, increase sediment loads and change stream or river geometry.

Ultimately the model will be used by managers and decision-makers to evaluate a decision support system for developing management strategies for attain water quality standards and protect beneficial water uses.

**Comments:**

- A more complete identification of why this modeling approach is being used as related to the three impacts is necessary.

*Response: A discussion of the rationale for developing and applying the model to the Columbia and Snake rivers is described in the Report*

- How was the decision made to develop this model? Was this an EPA directive? A request from National Marine Fisheries Service (NMFS)?

*Response: The model was develop by EPA Region 10 as part of the planning process in Section 303 (d) of the Clean Water Act.*

- The objective of this assessment should be made in the introductory section

*Response: The goals of the assessment are stated in the Introduction and a section entitled, Study Objectives, has been added to the Report.*

- Consider adding a short glossary of important terms

*Response: Suggestion noted*

## II. GEOGRAPHY, CLIMATE AND HYDROLOGY OF THE COLUMBIA BASIN

**Comments:**

- One of the sources of impact that this assessment is to address is watershed development. In that case, a more definitive evaluation of the watershed that may affect the water temperature of the study area should be identified.

*Response: This analysis focussed on the main stem Columbia and Snake rivers. An analysis of the watershed was beyond the scope of this assessment.*

- Reference is made to *confounding tributaries*. Where are these tributaries and what are the seasonal influence on the overall river thermal integrity?

*Response: The tributaries included in the analysis are described in the report as are the sources of temperature data for characterizing seasonal variations.*

- Can you prioritize which tributaries in the supporting watershed have the most potential for impacting the results of the assessment? Percentage or location wise which ones need to be concerned about?

*Response: The analysis of the watershed was beyond the scope of this report. Some additional discussion has been provided in the report elaborating on the relative importance of various tributaries.*

- The pre-project hydrology should be identified. This should be in two levels:
  a. Seasonal (monthly) perspective
  b. Daily regime (how much daily fluctuation occurred?

*Response: Pre-project conditions were not part of the analysis. The objective of the assessment was to evaluate the relative impact of dams and tributaries on water temperature given existing management of the system and variability in meteorology and hydrology represented by the period 1975-1995.*

- The post project hydrology regime for high, average and low water years should be presented. This would provide a spectrum of what the hydrologic boundaries. This is important in regards to evaluating the model.

*Response: Hydrologic data from USGS gaging stations on the Columbia and Snake rivers for the period 1975-1995 were used for the analysis. Data sources have been referenced in the Report.*

- The seasonal and summer/monthly flow regimes should be identified for the management of the dam complex. This is important in regards to interpreting

when the thermal thresholds occurred and how well the model predicted reaching the thresholds.

*Response: See comment above regarding source of hydrologic data.*

- An idealized hydrologic regime should be presented for each of the alternatives that the model is expected to be used to evaluate. In this way it can be determined how well the model is matching predicted flow scenarios.

*Response: Flows were not predicted in this analysis. See comment above regarding source of hydrologic data.*

## III. WATER RESOURCES DEVELOPMENT

This section of the report needs to be significantly expanded upon to address not only the time of development of the four dams but also what this has meant to the hydrologic and therefore thermal regime of the study area. The broad sense of the Columbia Basin development is addressed adequately however the specific relationship to the project area needs to be discussed.

**Comments:**

- Expand upon the development of the four study area dams. What impact did they have on the pre-project flow regime?

*Response: All the dams on the Columbia River below Grand Coulee Dam and all the dams on the Snake River below Lewiston, Idaho were included in the Report. Pre-project conditions were not evaluated in this study.*

- Discuss how the dams are operated. Are they operated as run-of-the-river, periodic storage, flood control, navigation, stabilization for downstream releases? Where is water withdrawn at the dams?

*Response: A discussion of dam operation, commensurate with the scope of the analysis, has been provided.*

- Discuss the physical and limnological effect of water resource development in the project area. Specifically add a section on the limnological relationships that occur as a result of flow regulation. Percentage of the time that stratification occurs? What is the residence time of water within the reservoirs?

*Response: The effects of water resource development will be discussed in a problem assessment of the Columbia and Snake rivers.*

- What are the upstream impacts as related to Hells Canyon dam releases? Does it have a seasonal warming effect? What are the input conditions and does it affect the thermal capacity of the study area?

*Response: The geographical scope of the analysis is limited to the Columbia River below Grand Coulee Dam and the Snake River below its confluence with the Grande Ronde River. Some of the effects of upstream management can be inferred from the magnitude and frequency with which temperatures exceed the benchmark at the upstream boundary.*

- Are there any impoundments on the tributaries that may be confounding the problem by providing seasonally warmer water?

*Response: This analysis focussed on the main stem Columbia and Snake rivers. An analysis of the watershed was beyond the scope of this assessment.*

- A *Biological Relationship* section should be added that identifies the critical biological threshold levels of the primary species of concern in the study area. This is important in that it provides a frame of reference in regards to evaluating the assessment. If the predictions are close to the threshold it is worth putting forth-additional efforts to fine-tune the numbers. If the predictions are not within the proximity of the threshold then not as much effort may be required to assess the trend or direction of the prediction.

*Response: A discussion of the biological effects of temperature on salmonids has been added to the Report.*

- What was the pre-project thermal profile for the river within the study area?

*Response: Pre-project conditions were not part of the analysis. The objective of the assessment was to evaluate the relative impact of dams and tributaries on water temperature given existing management of the system and variability in meteorology and hydrology represented by the period 1975-1995.*

- How was the 20-degree Centigrade level identified? Reference where this came from and what it is supposed to protect. Salmonids? Macroinvertebrates? Humans?

*Response: A discussion of the rational for choosing 20 °C as the benchmark and a discussion of the effects of temperature on salmonids has been added to the Report.*

## IV. STUDY OBJECTIVES

**Comments:**

- On Page 5 it is stated that the purpose of TMDL assessment is to:
  - Identify the sources of water quality parameters of concern
  - Identify what if any control or management strategies are possible

It is stated that the temperature assessment models will be used to provide some of the framework for a problem assessment in the mainstem Columbia

River. *Is this model ultimately going to be used for the development of the TMDL? If so, how was it determined that this was the best model for use?*

*Response: EPA and the states of Oregon and Washington have not yet determined how a TMDL will be performed on the Columbia and Snake rivers. A discussion of the rationale for choosing the model has been provided in the Report.*

- The objective of the assessment is defined as being to *develop and implement a mathematical model of water temperature for the Columbia and Snake Rivers in a way that is generally consistent with those of the screening model.* That stated, what is the level of detail that is required to address the questions being asked? In other words it should be stated how good the model has to be - within one degree? One level of statistical significance? Etc. The point is that it should be stated what the expectations and requirements are so that we can adequately determine if the model is meeting those objectives.

*Response: The level of significance necessary for subsequent planning and decision-making would be determined by the programs responsible for watershed planning. The uncertainty analysis provided in the assessment provides a basis of determining the level of significance or risk associated with using the model as a decision support tool.*

- Are there any biological or engineering objectives in this assessment?

*Response: The objective of the assessment was to evaluate the relative impact of dams and tributaries on water temperature given existing management of the system and variability in meteorology and hydrology represented by the period 1975-1995. Biological and engineering objectives would be part of the watershed planning process.*

## V. MATHEMATICAL MODEL DEVELOPMENT

This section has five (5) sections. Comments will be separated into the appropriate section.

System Boundaries

- No mention is made of the four reservoirs within the study area and the boundaries associated with them.

*Response: Characteristics of the reservoirs on the Columbia and Snake rivers are provided in the Report.*

- Are the tributaries included within the watershed system boundary?

*Response: A description of the tributaries included in the analysis are provided in the Report.*

- What are the hydrologic system boundaries associated with this assessment?

*Response: Hydrologic boundaries correspond to the thermal energy input boundaries. Tables describing the location of these boundaries are provided in the Report.*

- Figures similar to the "Surface elevations in Lake Franklin D. Roosevelt during 1998" should be made for each of the four reservoirs in the study area over a range of hydrologic regimes. This would help to identify the impacts of flow to the transfer of heat energy.

*Response: Characteristics of the reservoirs on the Columbia and Snake rivers are provided in the Report.*

- Was 1998 a "typical" year hydrologically and thermally at Lake FDR?

*Response: Surface water elevations for Lake FDR for 1998 provided an example of typical excursions in the volume of Lake FDR compared to those in the run-of-the-river reservoirs. While these time series may not be "typical" they are "representative" of the way run-of-the-river reservoirs are operated compared to the way Lake FDR is operated*

- The present baseline boundaries need to be identified for upstream and downstream positions on a seasonal basis.

*Response: A discussion of the geographic scope of the temperature assessment has been provided in the Report.*

Thermal Energy Budget

- The statement of *The thermal energy budget has proven to be a useful concept for simulating.....* needs to be referenced. Who has proven it?

*Response: A discussion of other applications of the thermal energy budget has been provided.*

- Have studies been done using the Eulerian approach rather than the Lagrangian approach? Where? How successful?

*Response: A discussion of various approaches to numerical modeling of water quality in rivers and reservoirs has been provided.*

- How are reservoir impacts accounted for in this approach?

*Response: Reservoir impacts are accounted for in this analysis primarily by the change in system geometry and by constraining the elevations of the reservoirs to be constant throughout the year.*

Solution Method

- What is a likely range of the Kalman gain matrix-weighting factor? Do large weighting factors connote large potential errors in evaluating the results of the assessment?

*Response: The Kalman gain matrix can vary from 0 to 1. A value of 0 implies that when making an estimate of the system all the weight is given to the systems model. A value of 1 implies that all the weight is given to the measurement. For values between 0 and 1 weight is distributed between systems model and measurement model according to their relative variance.*

- Define the Courant stability criterion (page 10)

*Response: A definition of the Courant stability criterion has been added to the Report.*

- It is stated on page 10 that the mixed Eulerian-Lagrangian method is used in the models. Once the river was subdivided into "N" segments for analysis was any validation done to check to see if the spatial segments provided the constant thermal properties necessary for the solution approach? In other words, once the model time and spatial steps were determined was there any work completed to determine if those assumptions were indeed correct?

*Response: The only test of the assumptions was to compare the simulated water temperatures and the observed water temperatures.*

- Can a flow diagram of the sequence of operations performed in the solution of the thermal equations be provided?

*Response: Comment noted*

Time and Length Scales

- Pre-project (development) hydrologic and thermal regimes need to be included in this analysis in order to ascertain the correct time and length scales.

*Response: Pre-project conditions were not part of the analysis. The objective of the assessment was to evaluate the relative impact of dams and tributaries on water temperature given existing management of the system and variability in meteorology and hydrology represented by the period 1975-1995.*

- Was a statistical analysis completed (with the existing data) to determine the variability of the pre/post project regimes? This would assist in determining the time and length step required.

*Response: A statistical analysis that is appropriate for the scope of the analysis has been added.*

- Is this model only going to be used to evaluate existing operations? Will there not be a need to determine what could be done if the alternative to breach the dams is evaluated?

*Response: The objective of the assessment was to evaluate the relative impact of dams and tributaries on water temperature given existing management of the system and variability in meteorology and hydrology represented by the period 1975-1995. No management options, including breaching of any of the dams, were analyzed in this Report.*

- What is the source of the geometric data? What is the stream channel variability?

*Response: Sources for the channel geometry are provided in the Report. The coefficients used to characterize channel geometry as a function of flow are also provided.*

Rationale for Approach

- Have any of the approaches identified on Page 12 gone through review to the level that the conclusion to use the mixed Lagrangian-Eulerian scheme is adequate for the quality of answer needed in this assessment?

*Response: A discussion of various approaches to modeling surface water quality is provided in the report.*

- Since it appears that development of the TMDL is a primary goal of this assessment, has EPA defined/recommended the level of detail required?

*Response: The objective of the assessment was to evaluate the relative impact of dams and tributaries on water temperature given existing management of the system and variability in meteorology and hydrology represented by the period 1975-1995. Decisions to conduct further watershed planning will be made by the program offices*

.

- Have other models been evaluated as potentially appropriate to this assessment?

*Response: A discussion of other surface water quality models and the rationale for model selection is provided in the Report.*

- Does the level of effort in this model match the level of quality required for the decision-makers?

*Response: EPA Region 10 believes the level of effort devoted to the model matches the quality required by decision-makers.*

## VI. DATA SOURCES

Comments:

- Is the quality of the tributary data consistent with the quality of the thermal data compiled by Laenen and McKenzie, 1998?

*Response: Quality of the tributary data, at least in terms of temporal coverage, is somewhat poorer than thermal data compiles by Laenen and McKenzie. Tributary data are generally collected on a weekly or monthly basis. Therefore, it was necessary to use interpolation methods based on local air temperatures to interpolate weekly or monthly observations to daily tributary temperatures. As noted in the report, this introduces some uncertainty into the final result. The magnitude of the uncertainty is related to the relative contribution of the tributary to the thermal energy budget of the main stems.*

- Is the thermal data spatially distributed adequately to allow for model evaluation? In other words are there thermal sampling points at locations where the model will be making intermediate predictions?

*Response: The thermal data, though at times of questionable quality, is spatially distributed adequately to allow for model evaluation.*

- How as the information in Table 5 consolidated for use in the model? Were representative sections used or were specific hydrologically important locations selected?

*Response: Geometric data was selected so as to provide spatial coverarage at a scale of one to ten miles.*

- Was channel roughness considered in the development of the model?

*Response: The steady-state gradually varied flow model, HEC-RAS, was used to describe system hydraulics as a function of flow. Channel roughness is a required input to HEC-RAS.*

- Are the gaging stations adequately spaced?

*Response: The gaging stations are adequately spaced*

- Is solar radiation important to the heat transfer evaluation? If so, was there any solar information collected?

*Response: Solar radiation is simulated using peer reviewed methods described in the Report.*

- Was time of water being impounded behind the dams considered in the assessment? What is the retention time of the reservoirs and is there any indication that seasonal, daily of vertical stratification occurs?

*Response: Hydraulics of the river in both the impounded and unimpounded condition were analyzed. System hydraulics play an important role in the thermal energy budget.*

## VII. PARAMETER ESTIMATION

**Comments:**

Deterministic Elements = Source term = heat budget + advected thermal units
Travel times of parcels = from system hydraulics

Probabilistic Elements = means and variances of the error terms for the measurement and the systems model*

- Input assumptions should be identified and prioritized as to their potential level of impact

*Response: Input assumptions have been identified in the Report.*

- Data limitations, assumptions, and approximations inherent in the modeling process introduce errors and inconsistencies into the assessment. Accumulated error can lead to the results of the model being unacceptable or incomplete. Based on that statement, the potential error sources for this analysis should be identified.

*Response: Input assumptions have been identified in the Report.*

- The input conditions should be identified.

*Response: Input conditions have been identified in the Report.*

- How were the three flow levels in the Columbia and Snake Rivers chosen? Are they the boundaries of operation? Averages? High, medium and low flows?

*Response: The objective of the assessment was to evaluate the relative impact of dams and tributaries on water temperature given existing management of the system and variability in meteorology and hydrology represented by the period 1975-1995.*

- Do these flow levels represent specific geomorphic constraints? Specifically is the high flow considered in the flood plain?

*Response: Actual flows for the period 1975-1995 were used in the analysis.*

- Figures 6 through 13 relate to the simulated and observed water temperatures for the period of 1990-1995 for eight dams. In some instances

the simulated results do not match the observed for both high and low periods. Is this difference due to lack of data? Does the model have less ability to accurately predict at the high and low ends of the projection?

*Response: Mean and standard deviations of the seasonal differences between observed and simulated have been added to the Report. In general, mean error is lowest during the summer months and of the order of 0.2 to 0.4 °C.*

- The concept of the innovation vector analysis and the application to figures 14 through 21 needs to be explained in more detail. Is this application identifying seasonal shifts in temperature? What does the scale represent (-3 to +4)?

*Response: A more detailed discussion of the innovations sequence has been added to the Report.*

- Figures 22 through 29 are comparisons of actual and simulated innovations. These graphs are hard to read in black and white and perhaps either radically changing the line thickness or using different colors would make them more useful. None-the-less, it appears that the comparison between the observed and simulated is not a good fit. These graphs need to be explained in the result section to help understand their relevance to the evaluation of system model bias and error. Table 11 helps but I really think that the difference between the sample and theoretical variance needs to be explained in relationship to the modeling effort.

*Response: An effort has been made to improve the graphics and the discussion of system model error.*

## IIX. MODEL APPLICATION

**Comments:**

- How were these three scenarios developed?

*Response: The three scenarios were developed as a controlled experiment to assess the relative importance of dams and tributaries on the thermal energy budget of the Columbia and Snake rivers.*

- Is the 16-degree Centigrade temperature regime from the tributaries achievable?

*Response: The rationale for choosing the 16-degree Centigrade constraint is based on the State of Washington's water quality criterion for water temperature in Class AA Extraordinary waters. However, the choice of this constraint was not meant to imply that this temperature was achievable. Rather, it was meant to assess what impact the lowering of water temperatures in tributaries would have on water temperatures in the main stems.*

- How was the benchmark of 20 degrees Centigrade chosen (page 18)?

*Response: A discussion of the rationale for the benchmark of 20 degrees Centigrade has been added to the Report.*

- Five areas of issue were identified that require subsequent analysis for future evaluation of Columbia and Snake River temperatures. Can the five areas be prioritized as to their:
    - Level of impact to results
    - Level of impact as related to model calibration
    - Level of statistical importance to evaluating the results

*Response: This setting of priorities would be the next of phase of the problem assessment for a TMDL.*

- Was irrigation return flow considered important in the analysis?

*Response: Irrigation return flow was not considered to be important other than as it affected the aggregate groundwater return flow and temperature.*

- Was reservoir retention and operation determined to be an important component of the heat budget

*Response: Reservoir retention and operation plays an important role in the temperature regime of the Columbia and Snake rivers. Reservoir geometry and operation determine the travel time through the two systems and also the rate of heat exchange across the air-water interface. The Report concludes that these are major factors leading to alteration of the temperature regimes of the two rivers.*

- Was evaporation considered to be an important element in model calibration?

*Response: Evaporation rates were adjusted, relative to the Lake Hefner coefficients, to reduce the bias in the difference between observations and simulations. The evaporation coefficients used in the analysis have been added to the Report.*

- Figure 30 through 35 and 36 through 41 are really the essential elements of this assessment. I would suggest overlaying the graphs (to show total change) or developing a table for the differences between the five dams and the frequency of exceedance would be useful for the RESULTS section. I also think an arrow indicating the direction of flow (upstream to downstream) would be helpful for interpretation sake.

*Response: Comment noted.*

## IX. RESULTS

**Comments:**

- Summarize the results with the graphics developed. Specifically it would be useful to overlay figures 30-32, 33-35, 36-38, 39-41. In this way each of the scenarios can be addressed with specific reference to changes predicted.

*Response: Comment noted.*

- Develop specific headings for each of the three scenarios and identify specific graphics (see above) to assist in evaluating them.

*Response: Comment noted.*

- A discussion on the model error as related to the results should be developed. Are the results statistically valid?

*Response: Discussion of model error has been added to the report. The question of statistical "validity" is more difficult since no protocols have been established for deciding what is a "valid" model. A more thorough discussion of this issue will be part of the problem assessment for any TMDL which might be performed.*

- Are the results for levels of exceedance within the statistical ability of the model? Specifically is a 1.4 degree variance at Grand Coulee dam supportable with the level of effort in a screening model? The point is it is that it might not be the actual number that is appropriate but instead be the trend that is seen. With the level of error imbedded in the coefficients and in the model-input data, it might not be safe to say that the actual change is 1.4 degrees. Instead it might be more appropriate to indicate that a thermal increase occurs and exceeds the threshold for specific salmonid species and life stages.

*Response: References to the level of effort as a screening model have been removed from the Report. The complexity of the model is similar to that of other analyses (Systems Operation Review, Lower Snake River Temperature and Biological Productivity Modeling) of the Columbia and Snake rivers. The results of the analysis imply that structural differences in the system resulting from dam construction and operation lead to increases in the thermal energy of the two rivers compared to that of the unimpounded rivers. The uncertainty in the state estimates provides a measure of how much improvement in the model and/or the measurement system is necessary to reduce the risk in decision-making.*

- Did the models perform as you hoped or was there a need to manipulate the coefficients to allow the model to balance?

*Response: The process used in this analysis was to use available measurements to estimate certain model parameters and then to use the resulting modeling to assess the impacts of tributaries and dam construction and*

*operation on water temperatures. The uncertainty analysis was conducted to provide a means for assessing the risks in using the model as decision support tool.*

- No discussion is included on how good the model did versus the actual temperatures. This should be a separate section on Model Validation in the result section. The results of the modeling are only as good as the model predictions.

*Response: See above discussions on the issue of model "validity". In addition, an extensive discussion of the philosophical problems with assessing model "validity" or "acceptability" has been added to the Report.*

- A separate heading on the results from figures 30-35 and a table would be helpful.

*Response: Comment noted.*

- A separate heading on the results presented in figures 36 - 41 and a table of results should be developed. Specifically in addressing whether the changes what are documented between 36 and 37 are statistically significant.

*Response: Comment noted.*

- When do the results exceed the 20-degree Centigrade threshold?

*Response: Only the frequency and magnitude of temperature excursions are provided in the Report.*

- How much natural (pre-project) variability can explain away the thermal increases (without dams) that is predicted?

*Response: Pre-project conditions were not evaluated in the Report.*

- What figure 39 tells me is this:
  - Water warms as it goes downstream
  - There is a thermal jump at McNary dam and this is due to the Snake River influence
  - There is a thermal jump at McNary without the four dams on the lower Snake River

  WHAT IT DOES NOT TELL ME is how significant the thermal difference is and if the model is good enough to believe.

*Response: See previous discussion on model "validity".*

## X. CONCLUSIONS

**Comments:**

- The conclusions are supported by the data presented.

*Response: Comment noted.*

- A DISCUSSION section should be included here to help interpret the results and conclusions drawn.

*Response: Some additional discussion and interpretation of results has been added to the Report.*

- Questions arise as to the level of detail of the model results as related to the changes identified. For example, is the model sensitive enough to allow for percentages as low as 1-3% to be valid? No results were presented that evaluated the level of change in model results that could be realized with small incremental changes in the model parameters. A section in the conclusions on the Model should be developed. This section would address how good you feel the model is as related to the applications.

*Response: The uncertainty analysis aggregates all the uncertainty and variability in the model, including that of uncertainty in the model parameters. Some additional discussion and interpretation of results has been added to the Report*

- Is the 1-3% increase due to Snake River dams (conclusion 3) due to upstream Snake River dams?

*Response: The effect of the upstream Snake River dams is the same for all three scenarios.*

- What is the level of error associated with the results and the therefore the conclusions?

*Response: See previous discussion of model "validity" and level of error.*

- Are there limits to the use of this model based on the results presented? My fear is that without identifying some limits anyone may think that it is applicable. For protection sake it might be wise to address future uses of the model (i.e. limits, assumptions, etc.)

*Response: See previous discussion of model "validity" and level of error.*

- Is a conclusion that the reservoirs increase the thermal condition in the river? If so then the reservoirs are indeed heat sinks and even though they may be run-of-the-river they do have an influence on the thermal character of the river. Therefore I strongly urge that you include (as I stated earlier) a section on reservoir dynamics.

*Response: The results of the analysis lead to the conclusion that the construction and operation of hydroelectric facilities on the Columbia and Snake rivers results in increases in the thermal energy load of the system compared to the unimpounded system. An analysis of reservoir dynamics would be an important part in the next phase of a problem assessment for the Columbia and Snake rivers.*

- A discussion on the changes that occur at McNary as a result of Snake River inflow would be helpful.

*Response: Discussion of the effect of the Snake River on the Columbia River has been added to the Report.*